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Three-Phase Transformer less PV integrated Shunt Active Power Filter with Reduced Switch Count for Harmonic Compensation

Sanjiv Kumar[1] , Dr. Sameena Elyas Mubeen[2]

M.Tech. Scholar, Department of Electrical &Electronics Engg. REC Bhopal (India)

Professor, Department of Electrical &Electronics Engg. REC Bhopal (India)

Abstract: Recent advances in power electronics have accelerated the integration of renewable energy sources, power storage, as well as modern loads into the hybrid microgrid connected with the smart grid. In this report, a Photovoltaic Array integrated shunt active power filter with harmonic compensation and active power injection is presented. To minimize the power rating of voltage source inverters, hybrid topologies integrating low-power ratings Active power filter with passive filters have been used. A transformer with a large number of passive components is used in hybrid APF topologies for high-power rating systems. For a three-phase Shunt active power filter, novel four-switch two-leg Voltage source inverter architecture is presented in this work to reduce system cost and footprint. A two-arm bridge design, 4 switches, coupling inductors, and sets of LC PFs are all part of the suggested topology. By removing the set of power switching devices, the third leg of the three-phase VSI is eliminated, allowing the phase to be directly connected to the negative terminals of the dc-link capacitor. When compared to traditional Active power filter topologies, the suggested design improves harmonic compensation and enables complete reactive power compensation. Active power is pumped into the network consumed by the load since Photo voltaic array is connected at the DC link. MATLAB Simulink software is used to examine the test system's results.

Keywords: Harmonics, hybrid topology, nonlinear load, power quality (PQ), Transformer less inverter, Grid-connected system

I.INTRODUCTION

Voltage and current harmonics are generated in the power distribution system as a result of the proliferation of nonlinear characteristic loads. Current harmonics cause issues such as power quality, reactive power, transformer losses, voltage harmonics, as well as harmonic resonance at the distribution level. [1]

Active technologies, such as shunt active power filters (SAPFs) and hybrid APFs, can help to solve these issues hybrid active power filter (HAPFs). The passive and active components of these filters are coupled in series or shunt connection. In accordance with tight harmonic regulations, these filters also restrict the current flow harmonic into the power distribution system. [2]

A.Non-Linear Load

When the input current into electrical equipment does not follow the impressed voltage across the device, it is said that the equipment has a nonlinear input voltage as well as input current relationship. Nonlinear loads include any equipment that uses some form of rectification. Nonlinear loads produce current and voltage harmonics, which can cause problems for equipment that is designed to operate as a linear load. Because of the harmonic producing sources (nonlinear loads) to which transformers bringing power into an industrial environment are attached, they suffer increased heating losses. The non-linear load is a three-phase bridge rectifier connected to the grid by the means of line inductor (Ll, Rl) feeding an inductive load (Rdc, Ldc) as shown in figure 1 shown below:

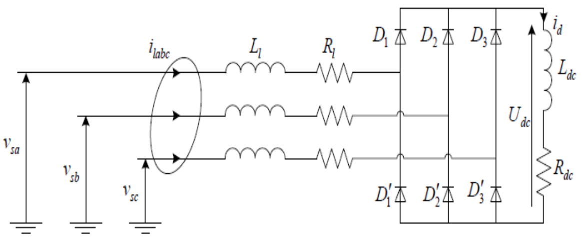

Figure 1: Non-linear Load

B.Three-Phase SAPF

The use of a Shunt Active Power Filter results in a significant reduction in these issues (SAPF). Active Filters can help you achieve the following objectives:

• Harmonic Isolation

• Harmonic Compensation

• Voltage regulation

• Reactive power compensation

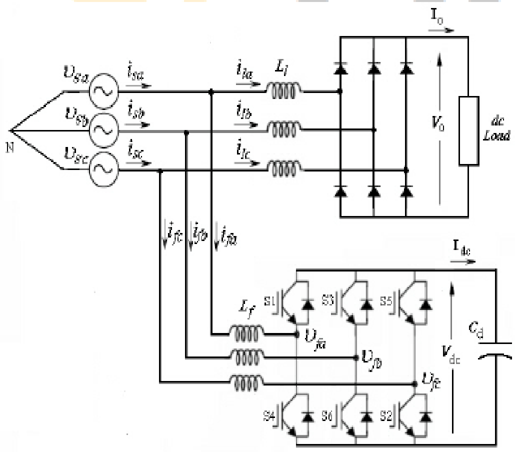

Figure 2: 3-phase SAPF Circuit

II.OBJECTIVES

For a three-phase SAPF, a novel four-switch two-leg VSI architecture is presented in this work to reduce system cost and footprint. A two-arm bridge structure, 4 switches, coupling inductors, and sets of LC PFs are all part of the suggested topology. The following are the study's goals:

• To give a brief overview about the cause and effect of harmonics in power system

• In the MATLAB/SIMULINK environment, modeling as well as simulation of a three-phase shunt active power filter with alternative current control strategies.

• The proposed design mainly aims to provide superior compensation capability and less complex structure without increasing the number of power switching devices for three-phase applications.

• The new topology provides superior overall performance as compare to the dc-bus midpoint connection configuration in terms of harmonic compensation capability owing to the balanced current and voltage.

• The proposed topology enhances the harmonic compensation capability and provides complete reactive power compensation compared with conventional APF topologies.

III.RESEARCH METHODOLOGY

The proposed SAPF is implemented in different load scenarios using MATLAB/SIMULINK in this research. Essentially, there are two simulations: one with non-linear load and the other with SAPF attached. A transformer-less SAPF architecture based on a four-switch two-leg arrangement is proposed in this work. The new circuit is developed from a six-switch full-bridge inverter, unlike previous current topologies. In comparison to traditional full-bridge topologies, the novel model improves harmonic filtering and reactive power correction.

The suggested design primarily intends to provide greater compensating capability and a less complex system for three-phase applications without expanding the number of power switching components. By minimizing the use of PFs, sequential ac-coupling inductors overcome the fixed reactive power compensation. Due to the extreme balanced voltages and currents, the new topology delivers better overall performance than the dc-bus midpoint connection design in terms of harmonic compensation capabilities.

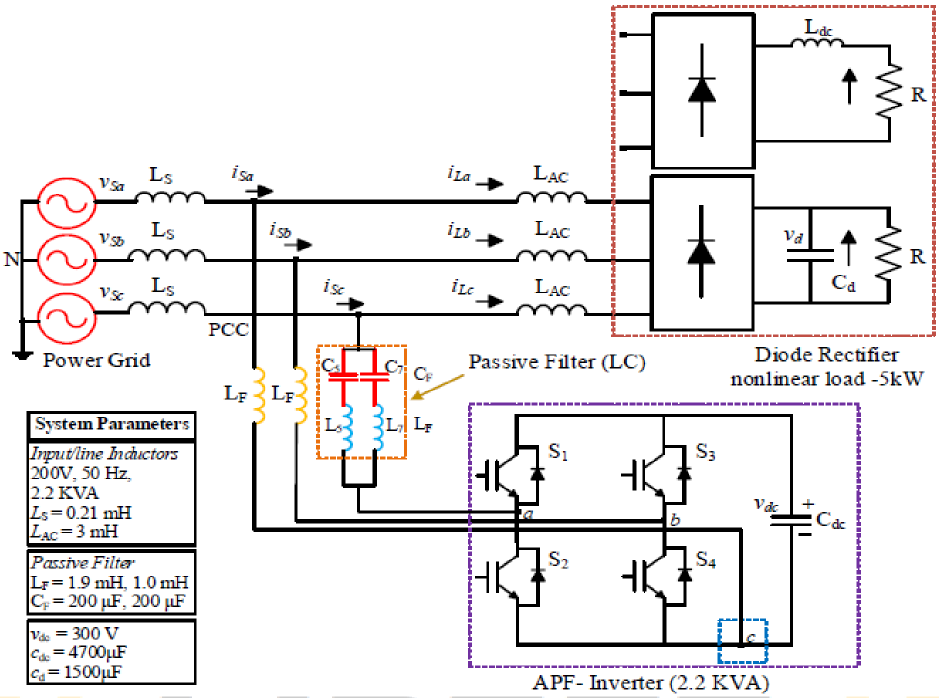

Figure 3: Proposed transformer less APF system

C.FOUR-SWITCH TWO-LEG VSI-SAPF

A two-arm bridge construction, four switches, coupling inductors, and sets of LC PFs are all included. For a good switching scheme, the sinusoidal PWM (SPWM) modulation strategy was used in this work. To design the reference signals, the carrier signal is compared to the comparators with a single alteration.

By removing the set of power switching devices, the third leg of the three-phase VSI is eliminated, allowing the phase to be directly connected to the negative terminals of the dc-link capacitor. The removal of a single phase-leg causes a voltage imbalance or voltage variations in the dc-link. To prevent imbalance charging of the dc-link capacitors, attach the removed leg terminal to the negative terminal of the dc-bus PWM-VSI. Additionally, the ac film capacitor holds decoupling power ripples to give balanced output voltages and currents, thus stopping the flow of decoupling power ripples. The new circuit is developed from the six-switch full-bridge inverter shown in, unlike many other previous topologies. In comparison to traditional full-bridge topologies, the novel model improves harmonic filtering and reactive power correction.

IV.RESULTS AND DISCUSSION

Simulation studies are carried out in the MATLAB/Simulink environment to validate the efficiency of SAPF with the suggested controller. This section contains the electrical parameters of the SAPF that were used in simulation experiments. In simulation investigations, two scenarios for steady state and transient state circumstances are explored, and the SAPF MatLab/Simulink Model is shown in figure 4.

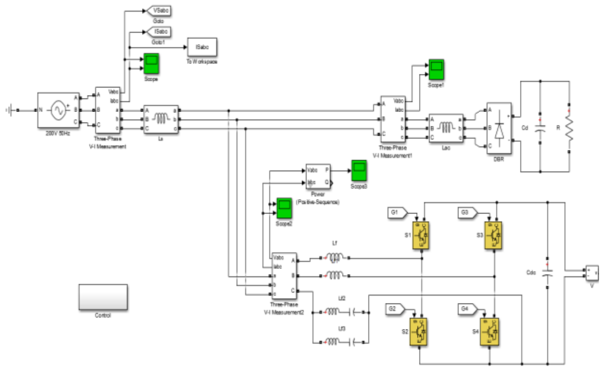

Figure 4: Transformer less Shunt active power filter system

The above is the modeling of the proposed test system with three phase source feeding non-linear load which injects harmonics into the system. The harmonics are compensated by the SAPF connected at the PCC of the test system.

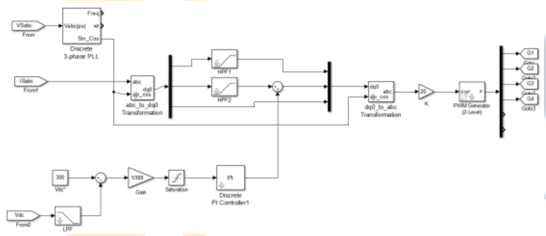

Figure 5: control modeling

The above fig. 5 is the modeling of the control structure for controlling the four switches of the SAPF operated by sinusoidal PWM technique. The below fig. 6 are the three phase voltages and currents of the source when the system is run without SAPF connected.

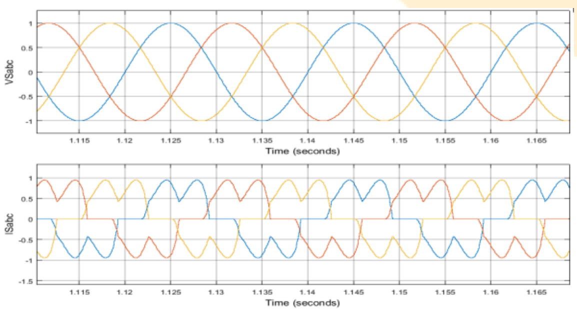

Figure 6: Source voltages and current without SAPF

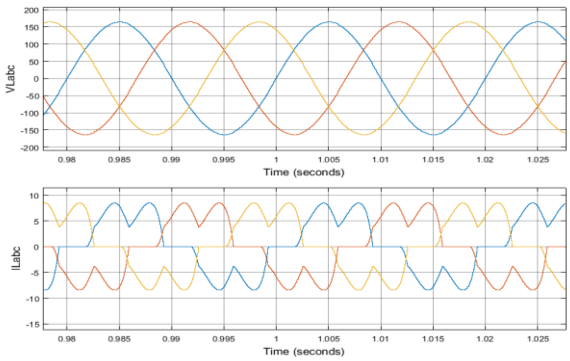

Figure 7: Load voltages and currents without SAPF

The above fig. 7 are the three phase load voltages and currents of test system without SAPF connected. The below fig. 8 is the FFT analysis of the source current to determine the THD without SAPF connected to the grid.

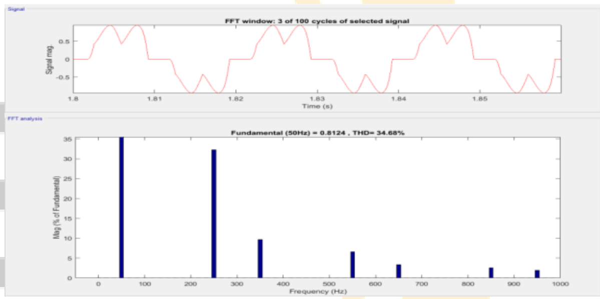

Figure 8: THD of source current without SAPF

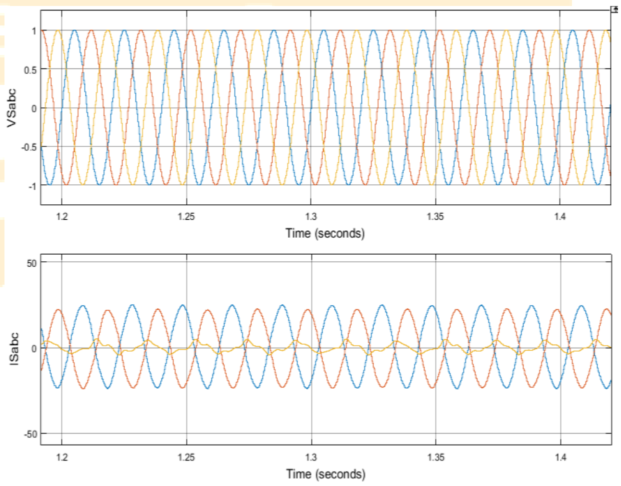

Figure 9: Source voltages and current with SAPF

The above fig. 9 are the three phase source voltages and currents with the system is connected with SAPF and the below fig 10 are load voltages and currents for the same.

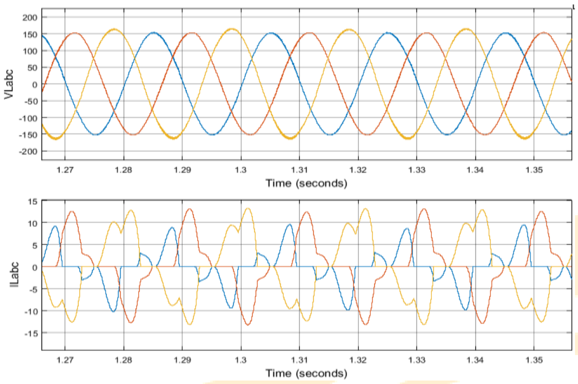

Figure 10: Load voltages and currents without SAPF

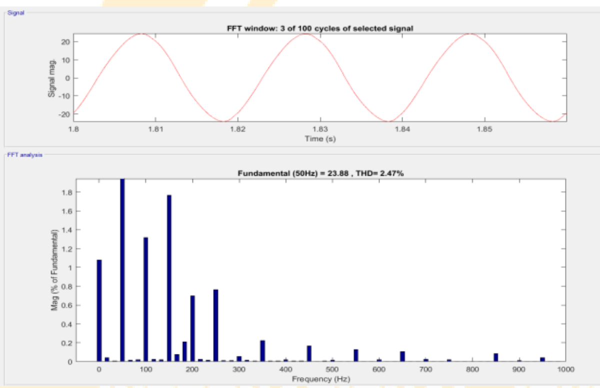

Figure 11: THD of source current with SAPF

The THD of the source current with SAPF can be observed in fig 11 and the active power injection from the SAPF can be seen in fig 12.

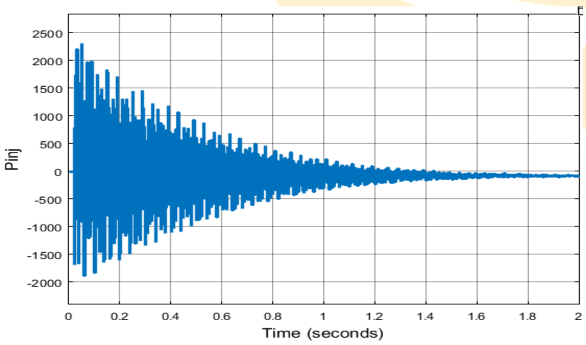

Figure 12: Injected active power of only SAPF

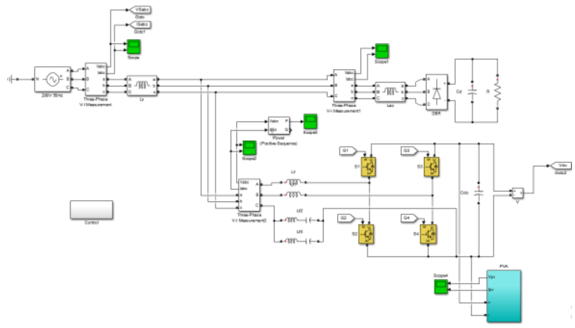

Figure 13: Transformer less Shunt active power filter system with PVA

The proposed test system shown in fig. 13 is updated with Photovoltaic Array connected at the DC link in parallel to the DC capacitor for renewable source power sharing.

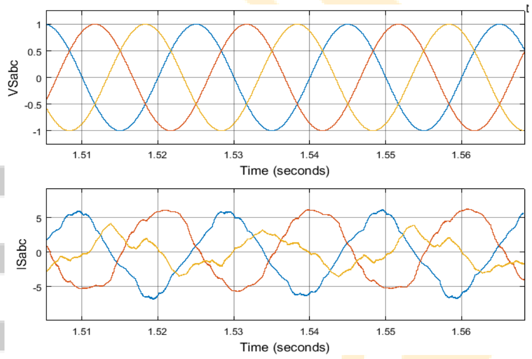

Figure 14: Source voltages and current with SAPF connected to PVA

The above graphs of fig 14 are the three phase source voltages and currents for the test system with PVA integrated SAPF and below fig 15 are the load voltages and currents for the same.

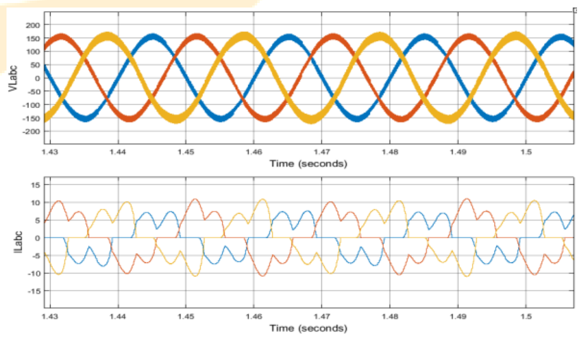

Figure 15: Load voltages and currents without SAPF connected to PVA

The below fig 16 are the PVA voltage and current shared for optimal solar irradiation.

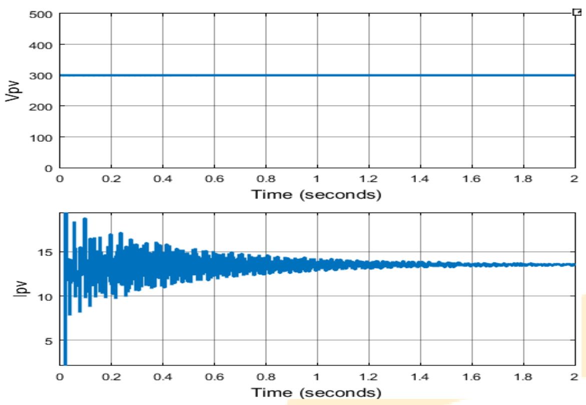

Figure 16: PVA voltage and current

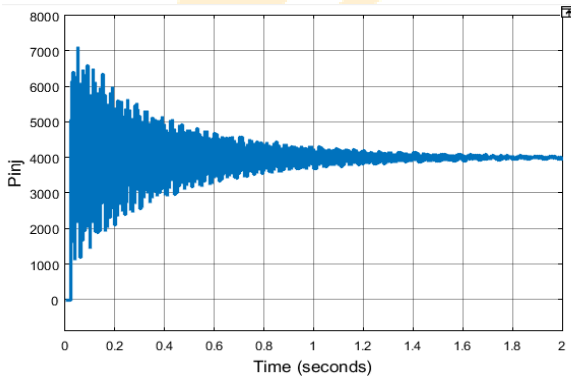

Figure 17: Injected active power of SAPF connected to Photo Voltaic array

The above fig 17 is the total injected active power from the PVA integrated SAPF to the grid system.

V.CONCLUSION

As observed the THD of the source current is reduced from 34.68% to 2.47% when Shunt Active Power is connected to the grid at PCC. And there is an active power injection of 4kW of power from the Photo Voltaic Array Integrated Shunt Active Power Filter module. The proposed APF system is more robust, efficient and stable to improve the feasibility and harmonic propagation of the power distribution system. A detail analysis of the both the active filter inverter and passive filter, including the active power capability and filtering characteristics has been presented. The control algorithm can ensure the regulated sinusoidal voltage, phase amplitude, and low THD in the power distribution system, along with dc-link voltage control. The complete simulation is carried out in Simulink environment of MATLAB software with graphs generated using powergui toolbox.

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